Sink-to-Sensors Congestion Control

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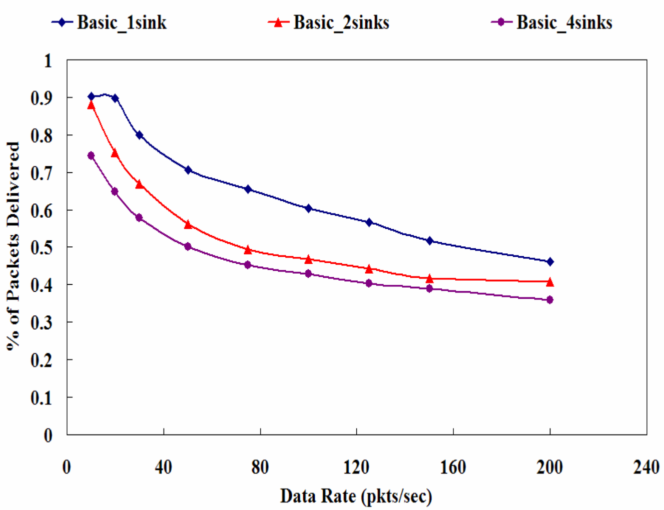
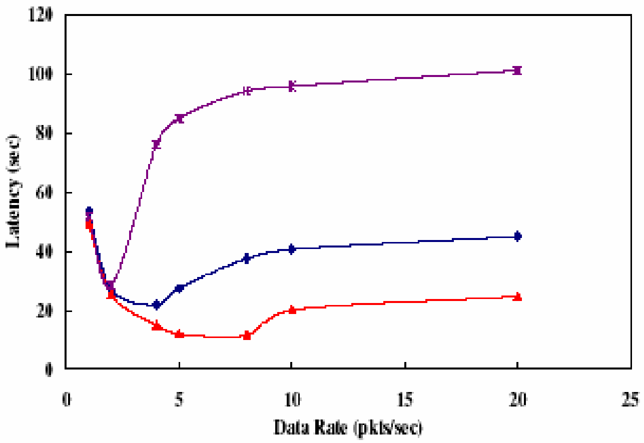
Example and Motivation

- Congestion is prevalent in wireless sensor networks
  - Reverse path traffic from sensors-to-sink
  - Broadcast storm problem: Increased contention and collisions due to series of local broadcasts
- Effect of congestion
  - No Reliability: percentage of packets delivered decreases with increasing data rate
  - Strict reliability: latency of reception of packets increases with increasing data rate





Congestion Control

- Congestion control is necessary in wireless sensor networks
  - For fast and reliable message delivery
  - Efficient use of available network bandwidth and energy resources
- ☞ Need for a congestion control approach that addresses downstream congestion in wireless sensor networks
- Network Model
  - We consider a multi-hop network with one or more sinks coordinating a static sensor field
- Receiver Model
  - We assume all or only a subset of nodes are receivers of the message sent by the sink

Challenges and Goals (1/2)

- Receivers and non-receivers:
  - Nodes can either be receivers or non-receivers
  - Resources of non-receivers must be utilized to a bare minimum
- Lack of buffering at non-receivers:
  - Non-receivers should not be required to buffer any transit packets
- Differing congestion levels:
  - Congestion levels can be different in different regions due to
    - Reverse path congestion in a localized region
    - Increased sensing activity
    - Differences in node density
    - Node failures
  - Congestion levels across different regions must be addressed accordingly

Challenges and Goals (2/2)

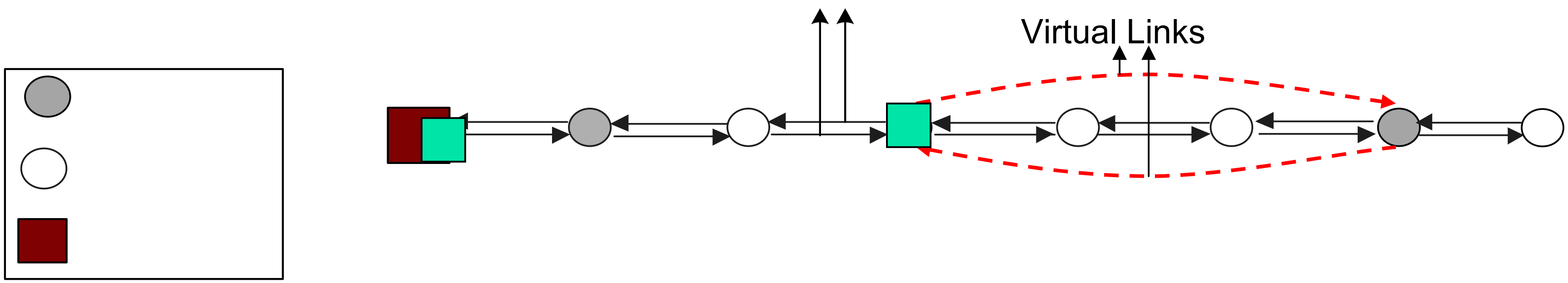
- Network dynamics:
  - Variation of congestion with respect to time
    - Node failures
    - Differences in sensing and reporting activity
    - Differences in reverse path traffic over a period of time
  - Changes in the congestion level over a period must be addressed
- Goals
  - Minimizing delay:
    - Receiver must receive the message through the fastest available path upstream of it in terms of delay
    - It should not be determined by congestion downstream of it or alternate slower paths
  - Efficient distribution:
    - Receivers and non-receivers should forward packets only if required by downstream nodes

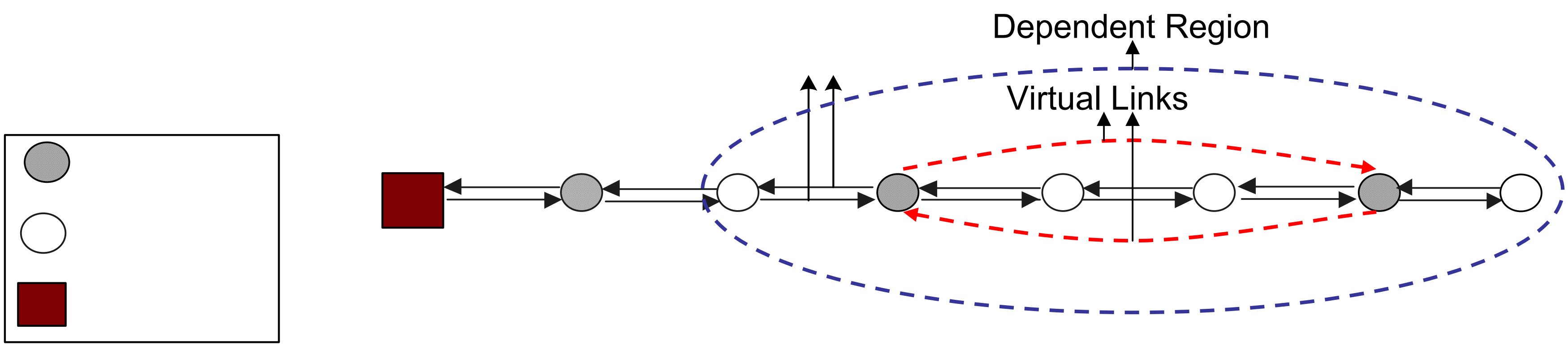
Design (1/4)

- Three components in the design of Congestion control from Sink-to-Sensors (CONSISE)
  - Determination of receiving rate of a receiver
  - Determination of sending rate of a receiver
  - Determination of receiving rate of a non-receiver

- Differentiating receivers from non-receivers
  - In CONSISE, each node maintains a receiving rate and a sending rate
  - Receiving rate: Rate of successful reception from an upstream node
  - Sending rate: Rate of forwarding from this node to downstream nodes
  - ☞ Sending and receiving rate of non-receiver are set to be equal (to the receiving rate): Addresses lack of buffering at non-receivers
  - Sending rate of a receiver is based on receiving rate of downstream receivers
  - Receiving rate of a receiver is based on the sending rate of upstream receivers

Design (2/4)





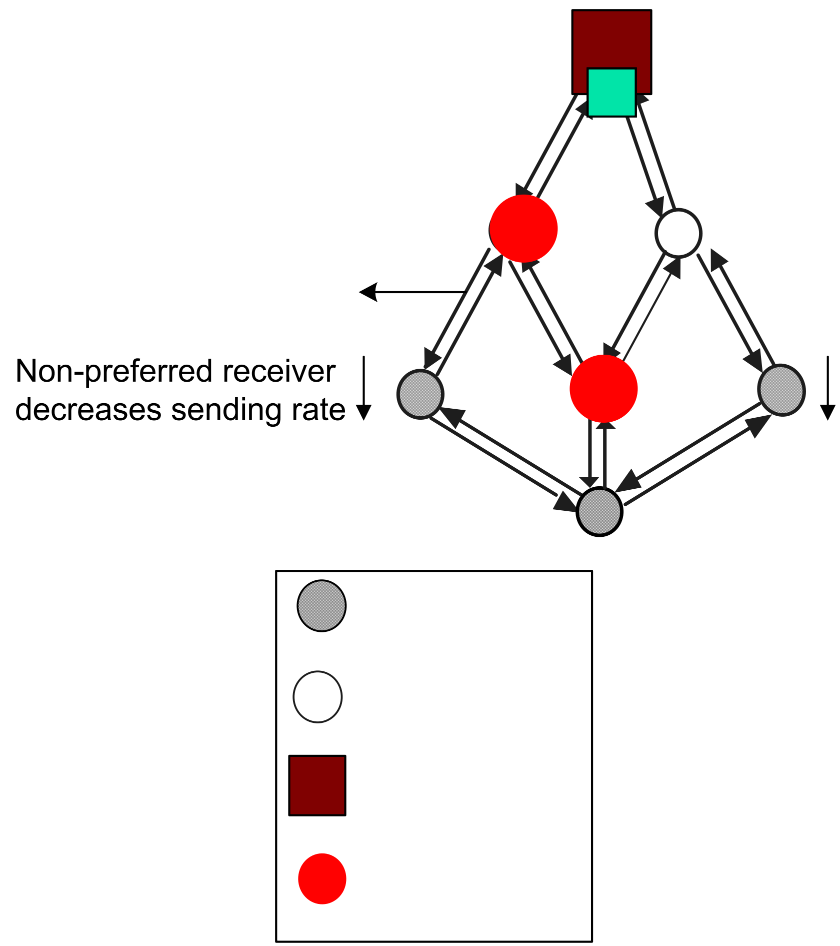
Receiver

Design (3/4)

- Handling different congestion levels
  - Sending and receiving rates are determined per epoch: Addresses network dynamics with respect to time
  - Dependent region based approach, where the region between two receivers is treated as a single virtual link: Address spatial variations in congestion level
  - Each node maintains maximum sending rate and sending rate
    - Maximum sending rate is based on the channel conditions of the current node
    - Sending rate is based on the channel conditions of the downstream node
- Fast reception for receivers
  - At the end of each epoch, every receiver selects the preferred upstream receiver
  - The preferred upstream receiver sets its sending rate based on receiving rate of downstream receivers
  - Preferred upstream receiver: Ensures fast reception of messages

Design (4/4)

- Selective transmission
  - After an epoch, if any downstream receiver chooses this node as the preferred upstream receiver, then the sending rate is set to the minimum receiving rate of the downstream receiver
  - If the upstream node, is not chosen, the sending rate of this node is gradually decreased to zero to minimize contention
  - Non-receivers forward only if they are along the path from the preferred upstream receiver to the downstream receiver
  - ☞ A node transmits only if it receives request from a downstream receiver: Efficient distribution



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Performance: Simulation Environment

- Experimental setup: NS2 simulator
  - 800 sensor nodes in 600m X 600m square area
  - Transmission range = 67m [Savvides'02], 5% loss rate
  - Strict reliability, all receivers: Out-of-sequence + NACK
    - Sinks: 1, 2, 4 corresponding to 800, 400, 200 nodes each
  - Strict reliability, few receivers: Out-of-sequence + NACK
    - Sinks: 2; each sink has 100 receivers (total=200)
  - No reliability: Out-of-sequence
    - Sinks: 1, 2, 4 corresponding to 800, 400, 200 nodes each
  - Broadcast, CSMA MAC protocol stack
  - Message size = 50 packets of 1KB size
- Metrics
  - Reliability
    - Number of data transmitted
    - Number of retransmission requests
    - Latency (sec)
  - No reliability
    - % of packets delivered

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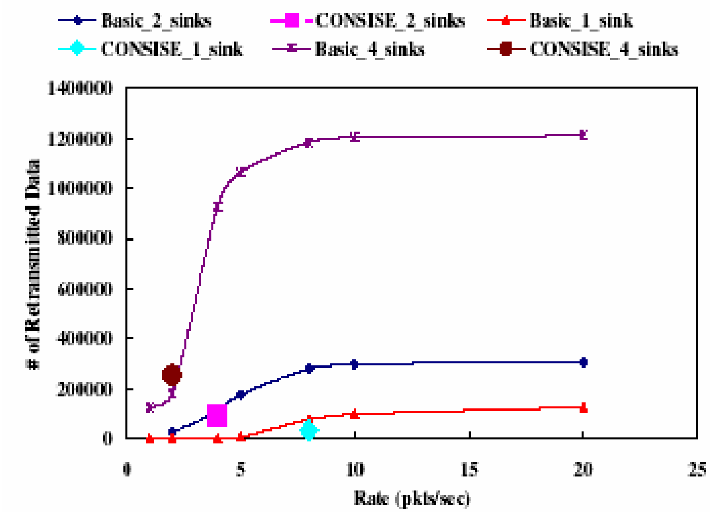
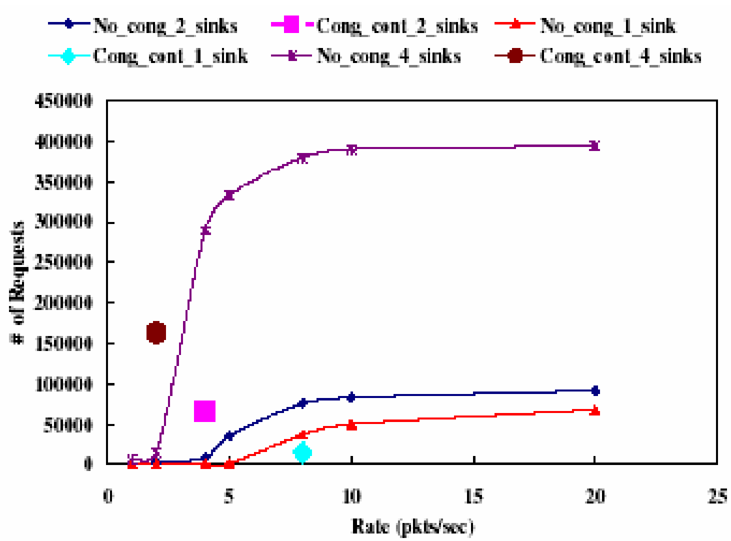
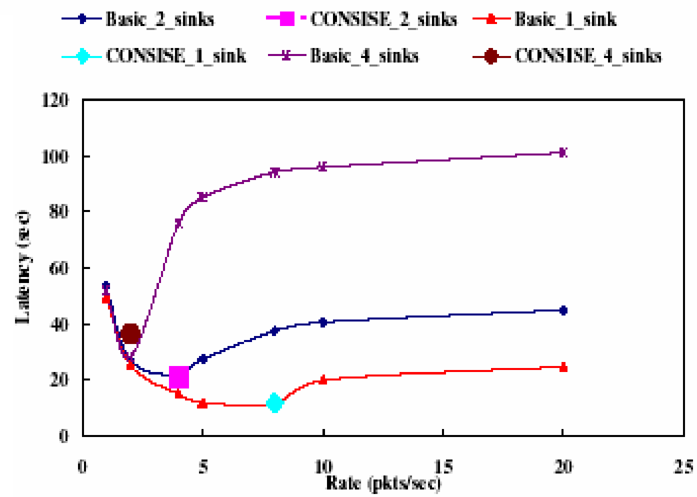
Performance: Strict Reliability, All Receivers

- ✓ CONSISE has lower retransmitted data
- ✓ CONSISE has lower number of retransmission requests
- ✓ CONSISE has a lower latency







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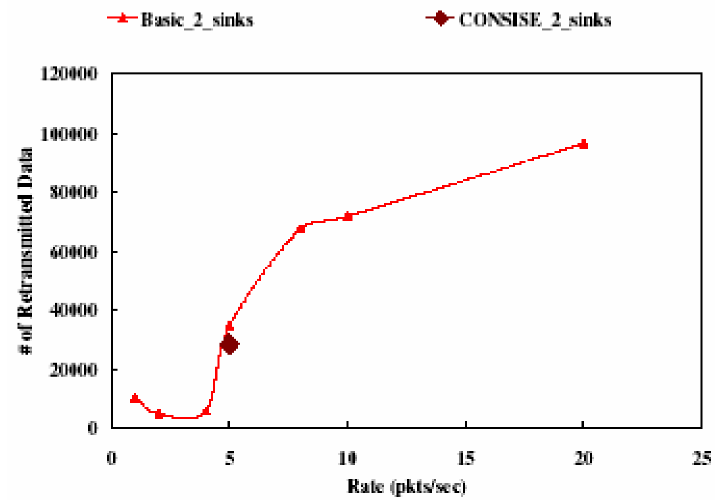
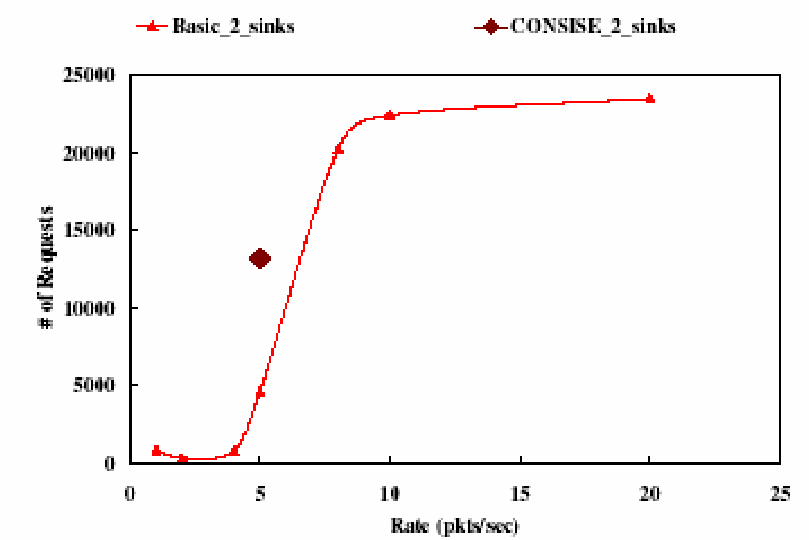
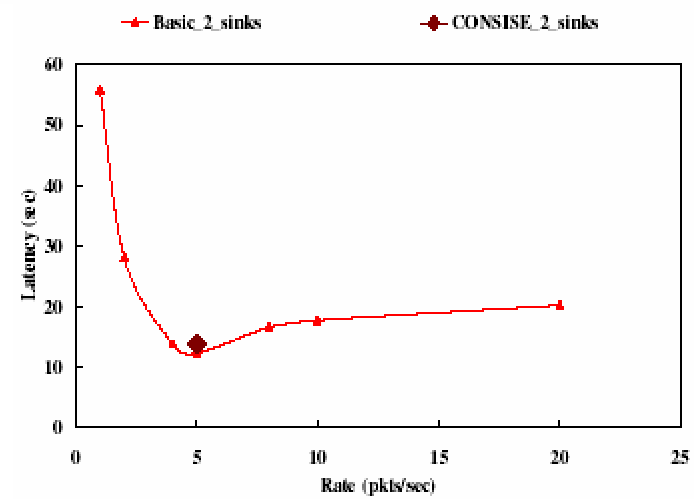
Performance: Strict Reliability, Few Receivers

- ✓ CONSISE has lower retransmitted data
- ✓ CONSISE has lower number of requests
- ✓ CONSISE has a lower latency







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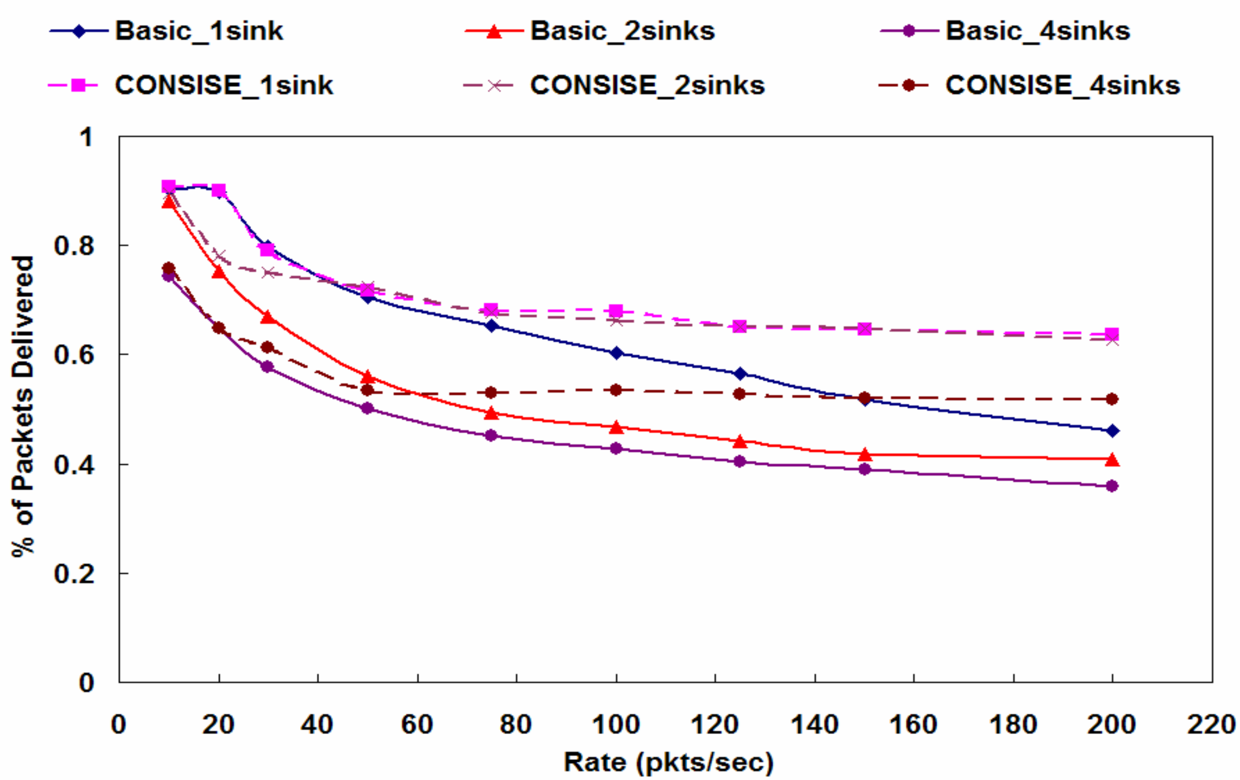
Performance: No Reliability

- ✓ CONSISE has higher number of packets received
  - Rate converges to optimum value
  - Epoch timer value needs to be adjusted to get better success rate



Related Work

- Existing approaches address congestion only in upstream direction in WSNs [Sankarasubramaniam'03, Wan'03]
- Downstream reliability approaches [Wan'02, Park'04] do not address congestion fully
- Efficient broadcast approaches [Ni'99, Williams'02] change the routing strategy and do not address local congestion
- Ad hoc multicast congestion approaches [Tang'01, Lee'01] are not suitable for sensor networks
  - Loss rate is high
  - Node density is high

☞ None of the approaches addresses the challenges associated with downstream congestion in WSNs